MODIS SEMI-ANNUAL REPORT
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CONTENTS

A. PERSONNEL

Personnel supported for the second half of 2003 include:

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V. Halliwell (Jul-Dec)
K. Kilpatrick (Jul-Dec)
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S. Walsh (Jul-Dec)
J.Splain (Jul-Dec)
O.Yenia (Jul-Dec)
I. Sanchez (Jul-Dec)
D. Wilson-Diaz (Jul-Dec)
J. Brown (Jul-September)
E. Kearns (Jul-Dec)

B. OVERVIEW OF RECENT PROGRESS

Introduction:

Major issues addressed in this revised code continued to focused on the temporal stability of MODIS ocean products over life of both the AQUA and Terra missions to date, to enable reprocessing and create a climate quality data record. As a result of the code and algorithm changes discussed in the last report; e.g. revised L1b, new solar constants, new polarization table, addition of Morel BRDF algorithm, sun-glint with polarization term (see Evans semi-annual report Dec-June 2003), the Oceans radiance correction LUT (RADCOR) for both AQUA and TERRA was completely revised. These LUTs were installed into the TERRA reprocessing stream in late October 2003, and the AQUA forward stream January 1, 2004.

B.1 Processing and Algorithm Development

Ocean color

The new approach used to develop the final gain correction for each bands was changed from that reported for earlier versions. For the Collection 4, reprocessed version 041 products and the planned AQUA reprocessing that had been scheduled for March 2004, the blue, green, and red bands where each adjusted with differing techniques. The blue band gains were adjusted relative to satellite in situ MOBY at the Hawaii validation site using only data collected during winter months. It is assumed that residual error in the l1b calibration is minimal during this time period as these represent the times when the satellite is least affected by potentially confounding residual errors in regard to sun glint and polarization. It is also the period where MODIS showed the best agreement with SEAWIFS. We have adopted an expectation that the blue band calibrations are relatively slow and behave in an exponential mode. Three calibration epochs are present in the RADCOR, one for each annual time period. A least squares fit between epochs was used to establish the time trend, calibration factors for a given data-day are interpolate along this curve. The blue bands were first adjusted to bring agreement with MOBY in situ data. After anchoring the blue bands to MOBY, the green band calibration was adjusted to force the satellite blue/green band ratio to match the entire MOBY in situ blue/green ratio time series, thus the green bands have numerous epochs. This was done to increase consistency in Chlorophyll products, as these algorithms are driven by the blue/green ratio, rather than by the absolute calibration of any given band. The red bands used for the Fluorescence products were adjusted to make the FLH consistent and within agreement of the MOBY/FOS measurements. Due to the relatively low seasonal variability at Hawaii for chlorophyll and the almost constant radiance in the red bands as measured at MOBY, the MODIS red bands were adjusted to reflect the in-water measurements and produce a relatively consistent FLH at Hawaii across the seasons. The combined effect of measured solar diffuser based L1b calibration and this revised RADCOR has the desired effect of reducing the 412 nLw seasonal oscillation by approximately 20% in the Southern Hemisphere high latitudes, and improves the overall temporal stability of the radiances and chlorophylls. However, it does introduce an increase in uncertainty for water leaving radiances products and does not address the seasonal and latitudinal oscillations in the MODIS to SeaWIFS water leaving radiance comparisons. These oscillations appear to be driven by as yet unresolved sensor calibration issues.

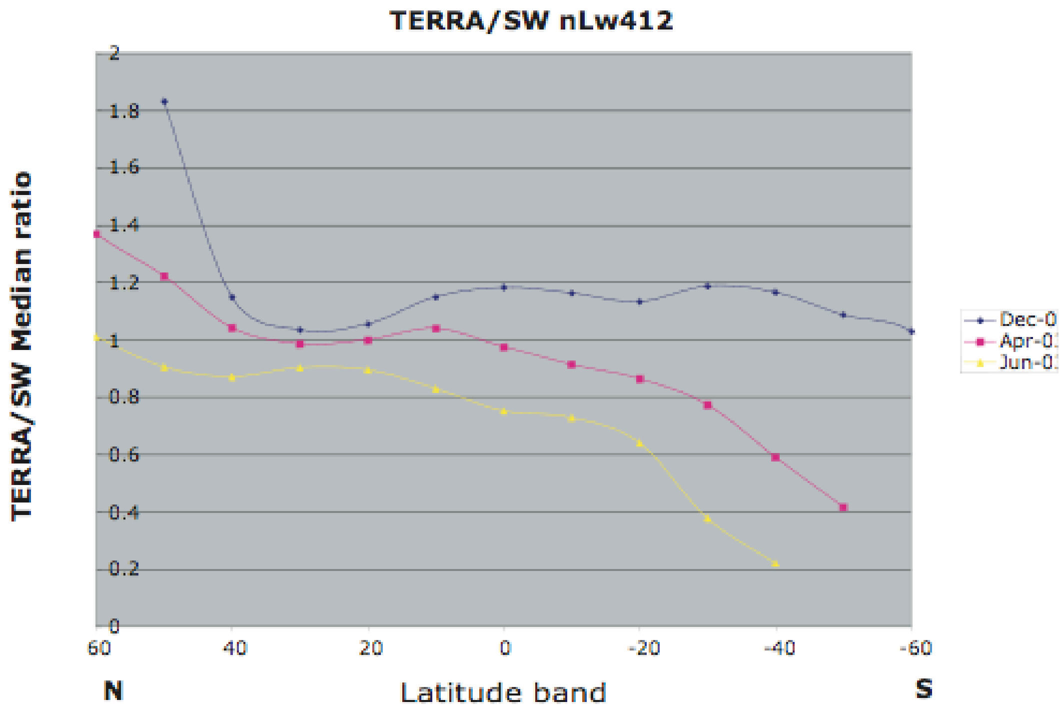
The complete reprocessing of the TERRA mission was completed in mid December. While Definitive comparisons of global Level-3 SeaWiFS and the MODIS Collection 041 extended time series was underway Analysis of both the archived TERRA collection 4, AQUA Collection 3, and TERRA Collection 041 global 2-days/month test data indicate that while on average there is generally good agreement with chlorophyll, (SeaWiFS = 0.185 +/0.02, MODIS = 0.179+/- 0.02 mg/m, Franz 2003), outstanding seasonal and regional biases are not completely eliminated and are currently under further investigation .These outstanding biases are not captured by the traditional validation "gold" standard of collocated *in situ* /satellite matchups, due to the limited time and space distribution of high quality *in situ* ocean color measurements.

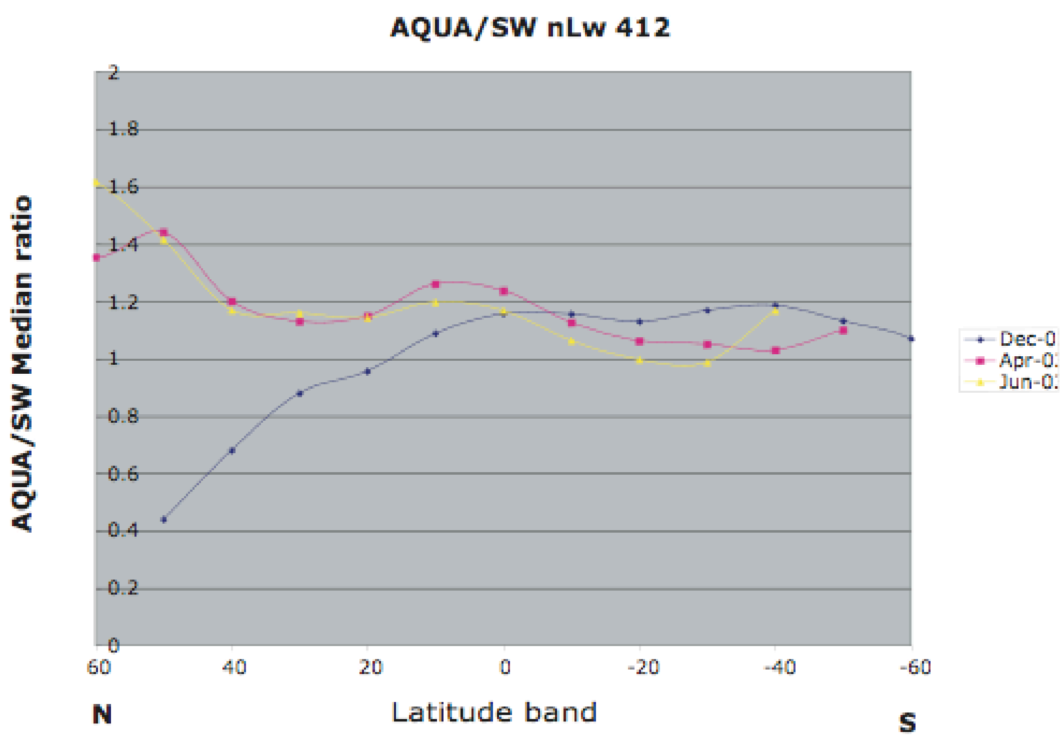
Comparison of SeaWiFS and Terra-MODIS water leaving radiances and analysis of Terra-MODIS and MOBY mooring *in situ* observations show differences in the retrieved water leaving radiances from less than 5% near the MOBY site to seasonal southern hemisphere differences that approach 30%. This difference of 20-30% in water leaving radiance translates to a 2-3% error in total top of the atmosphere radiance measured by the sensor. This discrepancy is by far the largest unresolved factor remaining in the MODIS calibration effort.

Inter-sensor comparisons of same-day water leaving radiance retrievals and clearly demonstrate that issues remain for both AQUA and TERRA MODSIS sensors in regard to maintaining calibration along orbit and seasonally. Figure 1a presents comparisons of the median MODIS/SeaWIFS ratio in ten-degree latitudinal zones for three seasons, December, June, and April. Terra nLw412 exhibits a progressive increase relative to SeaWiFS in the Southern hemisphere as a function of season. This increase is greatest (60%) at high Southern latitudes during austral winter (June). Since the Hawaii calibration site is frequently impacted by sun-glint in June, only December calibration points were used to develop the latest oceans calibration LUT. This technique did successfully remove 20% of the seasonal S.H. oscillation. The same analysis for AQUA, Figure 1B, shows almost an inverse relationship to Terra. The increase in radiance is present at very high Northern Hemisphere latitudes during winter (December).

Several different factors have been hypothesized as an explanation, and the leading potential candidates fall into two classes: 1) Factors active during level-1 calibration coefficient (called "m1") determination, and 2) Factors that impact the ability of the sensor to maintain the calibration along orbit.

Figure 1. nLw412 zonal 10 degree averages of median %difference MODIS-Seawifs/Seawifs for three seasons. Panel A. TERRA-MODIS Panel B. AQUA-MODIS





Class 1: Potential Level-1 calibration coefficient sources of error

- Excess radiance on the MODIS solar diffuser (SD) due to Earthshine
- Excess radiance on the MODIS SD due to uncertainties in the effects of SD attenuation screen
- Uncertainty in the SD bi-directional reflectance (BRF) correction
- Uncertainties in the focal plane temperature corrections

Class 2: Maintaining calibration intra-orbit and inter-season

- Stray light in the optical path from Earth view
- Detector-based temperature correction estimates
- Changing polarization sensitivity
- Uncertainties in the focal plane temperature correction

Work by a number of investigators in the MODIS community was proceeding by examining the Terra-MODIS L1A and L1b time series, modeling the effects of the MODIS Solar Diffuser attenuation screen vignetting function, calculating Solar Diffuser earthshine contributions, determining possible Earth View stray light contamination, and improving polarization modeling. As results became available, MCST had planed to prepare a series of revised level-1 lookup tables to be tested at the Miami oceans scientific computing facility to determine how each of these factors are contributing to the remaining errors. The first in this series of evaluation Level-1 calibration lookup tables (LUT's), containing fitted SD m1's, was delivered on 15 October 2003. The second LUT, revised RVS coefficients, was delivered by MCST to Miami on 7 November 2003. Depending on the results of the other studies, additional LUT's may be delivered as they are produced. MCST had anticipated that these studies and evaluation LUT's would be completed prior to the AQUA reprocessing in March 2004.

With the recent announcement of the MODIS re-competition results and NASA Headquarters decision to abandon both the MODIS ocean code developed by the University of Miami under this contract and cease processing TERRA-MODIS Oceans on February 1,2003 it is unclear if these new directions to better understand the MODIS instruments will continued in the future.

Expected benefits if the sensors are better characterized and understood:

Calibration -Improved understanding of errors in m1 determinations should reduce noise in the bi-weekly LUT m1 updates and thus reduce uncertainties in the retrieved water leaving radiances. Earthshine, uncertainty in the SD attenuation screen vignetting function, temperature corrections, and BRF of the SD are all currently being investigated.

Temporal variability in nLw -- Comparison of the along -orbit total top of the atmosphere radiance minus the Rayleigh scattering component with the computed sun-glint pattern suggests that excess radiance is present. Potentially, this excess is a result of stray light present during normal earth view observation. The presence of excess light is also supported through examination of the L1B visible channel data on an orbital basis as well as by comparison of the visible channel radiance patterns with that seen in the 4_m infrared bands. Additionally, another potential source of temporal error is the incomplete correction for sensor temperature sensitivity. The removal of the stray/excess light and/or thermal influences from the L1B products will likely eliminate the majority of the very large seasonal/latitudinal biases now present in the MODIS products.

Along Orbit Calibration Considerations-- The temperature and stray light effects that impact MODIS temporal calibration stability also effect the along orbit stability. Two additional challenges must be addressed to properly characterize the along orbit calibrations. These include:

Response vs. Scan --RVS correction is dependent upon the on board calibrator performance (OBC), and should improve as the OBC corrections improve. These measurements are used to monitor the change in cross-scan system response of the two sides of the MODIS scan mirror. Improvements in this area should reduce mirror side banding artifacts at high scan angles.

Polarization Sensitivity --Polarization characterization is totally dependent upon pre-launch studies, which lack desired accuracy. OBC's cannot address this. An optical modeling approach is underway to improve our understanding of how polarization sensitivity and radiometry may be changing with time due to mirror degradation. Improved understanding of the polarization should improve both seasonal east-west biases and mirror side banding. A current estimate of polarization sensitivity is approximately 12% for the 412nm band.

Sea surface temperature

B2. Matchup databases and Validation activities

Both the sea surface temperature and ocean color 1km matchup databases were extended in time to the current leading edge. The entire life of the mission matchup databases were reprocessed several times to explore, quantify, and validate code and coefficient changes. Aggregate globally distributed matchup statistics, Tables 1&2, for each sensor demonstrates the instrument and algorithm are performing quite well with respect to in situ observations. These statistics are comparable to those obtained for the AVHRR pathfinder SST. Time series plots (not shown) show no trends and indicate that both sensors appear stable with respect to both time and latitude. These overall statistics are comparable to those obtained for the AVHRR pathfinder SST. Further analysis with respect to mirror side and satellite zenith angle suggests that further improvements are possible to increase the accuracy and reduce uncertainty. Figures 3 and 4 show the median of residuals segregated by mirror side, and satellite zenith angle in 10-degree intervals across the scan line for matchups wet atmospheres.

Table 1, TERRA SST matchup statistics, Satellite SST – in situ SST. Median, standard deviation, and number of matchups.

Terra MODIS SST Buoy & M-AERI Retrieval Statistics
Mainly 2002, 2003

	Buoy + M-AERI			**Buoy (bulk)**			**M-AERI (skin)**		
	$\overline{T}$	T'	n	$\overline{T}$	T'	n	$\overline{T}$	T'	n
SST (day +night)	-0.140	0.478	15801	-0.104	0.478	15412	-0.022	0.448	759
SST (night)	-0.081	0.433	6648	-0.081	0.432	6392	-0.062	0.412	457
SST (day)	-0.182	0.504	9153	-0.182	0.503	9020	0.039	0.491	302
SST4 (night)	-0.124	0.370	6222	-0.131	0.370	6001	-0.029	0.363	404

Table 2, AQUA SST matchup statistics. Satellite SST – in situ SST. Median, standard deviation, and number of matchups.

Aqua MODIS SST Buoy & M-AERI Retrieval Statistics
Mission to October 2003

	Buoy + M-AERI			**Buoy (bulk)**			**M-AERI (skin)**		
	$\overline{T}$	T'	n	$\overline{T}$	T'	n	$\overline{T}$	T'	n
SST (day +night)	-0.053	0.492	14768	-0.054	0.494	14443	-0.034	0.402	325
SST (night)	-0.095	0.451	6557	-0.094	0.454	6381	-0.103	0.370	176
SST (day)	-0.020	0.520	8211	-0.021	0.522	8062	0.048	0.425	149
SST4 (night)	-0.106	0.395	5412	-0.107	0.397	5258	-0.074	0.341	154

Figure 3, TERRA SST residuals as a function of mirror side and satellite zenith angle

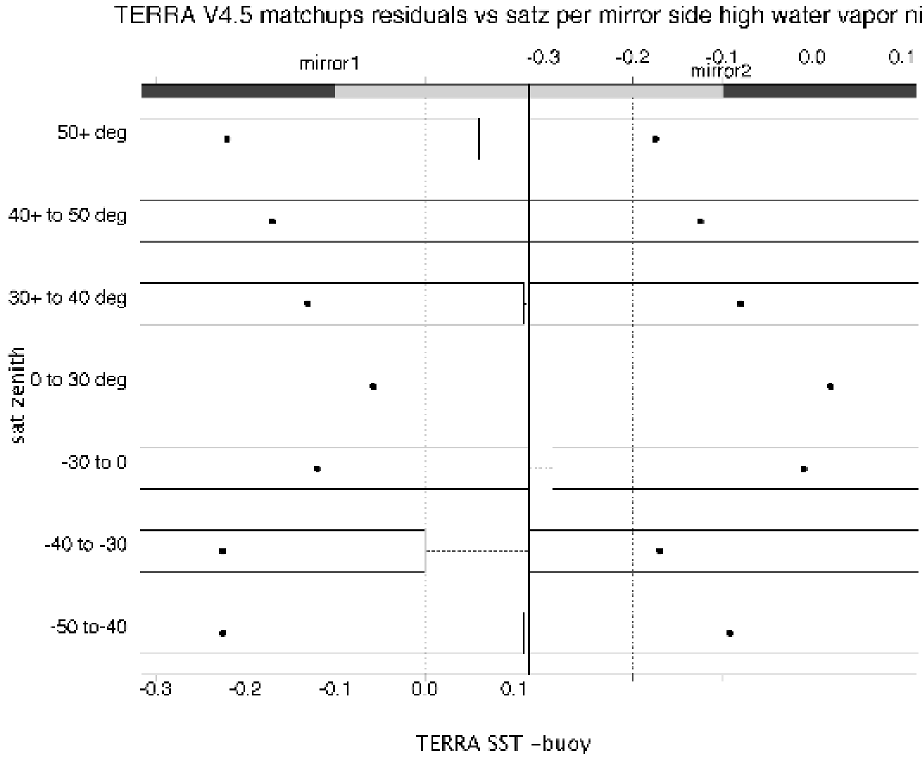
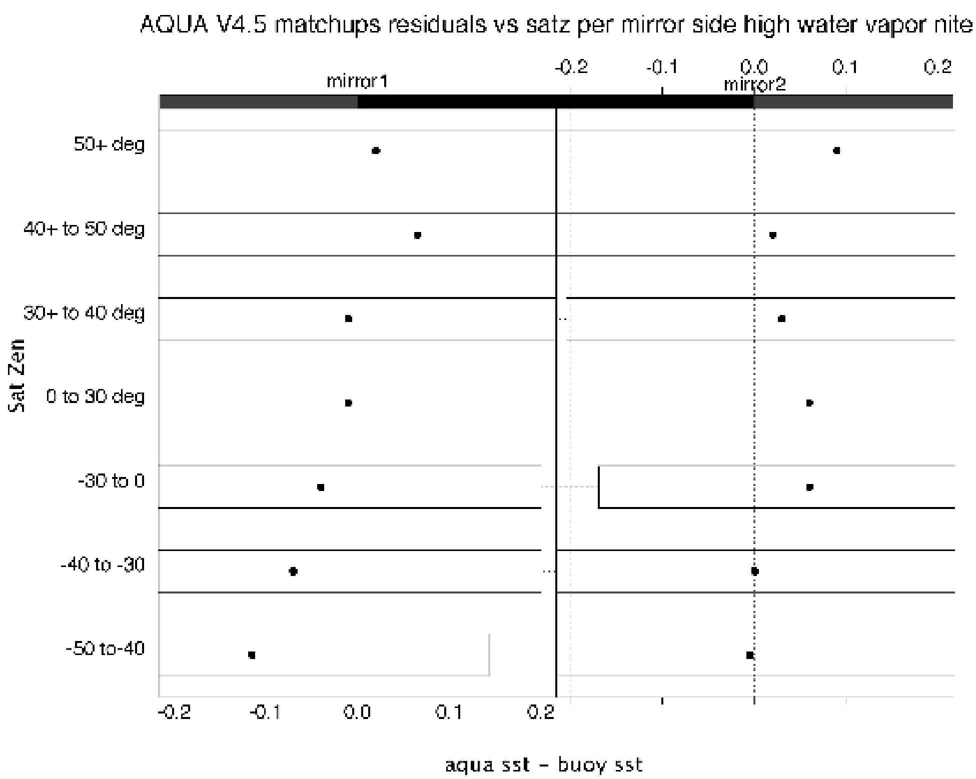


Figure 4, AQUA SST residuals as a function of mirror side and zenith angle



The TERRA residuals, Figure 3, show a "classic V" shape suggesting a small error in the atmospheric/ 4th term of the algorithm, the apex of the “V” is at nadir at the expect 0.05-0.1 skin-bulk offset. The sensor measures skin temperature and is generally expected to be to between colder than in situ buoys. TERRA’s two mirror sides appear to behave in a similar manner. Algorithm coefficients are being re-estimated based on these results to improve the 4^{th} term of the equation.

In contrast for AQUA, Figure 4, the two mirror sides do not behave the same, and "classic V" shape is not present. These results suggests that an RVS problem exists as there is a suggestion of a slope across the scan, in addition the nadir values are near zero rather than at -0.5 to -0.1 as might be expected. Examination of the AQUA low water vapor regime d3132 <0.7 suggest a more flat line with a hint of a "V" with respect to sat zenith angle with an offset at ~-0.1 at nadir for both mirror sides. However, more in situ matchups are needed in the high latitude dry and cold atmospheres to confirm these results. The fact that the trends may only present in high water vapor regimes suggests that the RVS problem may be restricted to band 32, as it is in these conditions that band 32 comes into play thru the band 31-32 difference term. In the low water vapor ch31 is dominating the equation. Currently the AQUA RVS correction done by MCST is based on per-launch characterization, while TERRA RVS is based on close door data obtained post launch. In the future in may be useful to obtain AQUA closed door data to improve the RVS correction.

B.3 Direct Broadcast and Miracle Web site

Direct broadcast

The Miami level 2 direct broadcast web pages and 14 day rolling archive including data and images from both AQUA and Terra Sensors continues operational during this period.

B.4 Systems Support

modcol:

Fix calculation of time of middle of granule to account for granule whose start and end days are different. Check for invalid NIR databefore performing atmos. correction. Exit with error if it can't read the L1b attributes. Check for ascending or descending if L1b flags are set, but not if geolocation flags are set. Use Day/Night mode to set AscendingDescendingFlg if geolocation is bad. Add ability to disable glint correction for testing. Return error value instead of calling exit. Move secnds to io library because mfill uses it also. makefile changes for linux. Don't need HDF5LIB. Make array bigger for long file names. Change and add some debugs.

modsst:

Print MET and OZONE file names to log file properly. Remove unused variable. Check for ascending or descending if L1b flags are set, but not if geolocation flags are set. Use Day/Night mode to set AscendingDescendingFlg if geolocation is bad. makefile changes for linux.

msbin:
Change COMFLG, MASK, and CLDMSK arrays so that they are per product. Take out debugs. makefile changes for linux.

mtbin:
Add HDF5INC to makefile for linux.

mspc:
Add HDF5INC to makefile for linux.

mmap:
Add HDF5INC to makefile for linux.

modlib/modisio:
makefile changes for linux.

modlib/mocean:
Commented out first attempt to not fill SDS's when file is opened. Fix GetBandPixelType to return CHAR type for INT8 or CHAR8. makefile changes for linux.

modlib/rtlib:
Fix comment in header.

modlib/Mwrap:
Add -DLINUX to makefile for linux.

modlib/io:
makefile changes for linux. Move secnds here because modcol and mfill use it. Don't want -g3 for linux.

modlib/anc:
makefile changes for linux. Add makefile for linux. Clean up and use Intel compilers.

modlib/invgeo:
makefile changes for linux.

binshr:
Change COMFLG, MASK, and CLDMSK arrays so that they are per product. Reduce AZSIZE to a more reasonable number for modis 5 minute granules and ‘4km' bins. makefile changes for linux.

mcolshr8/colorsub8.c:

Don't mix integer and real constants in an equation.

msstshr5:
makefile change for linux.

mfill:
Use secnds from io library. Add DSP5INC to makefile.

mcloud:
makefile changes for linux.

img2hdfbit:
Add HDF5INC to makefile for linux.

taitoutc:
Add HDF5INC to makefile for linux.

mextract:
Update path for alpha. Archive recent improvements to script. Use traditional C style comments (for alpha). Take care of another system dependent program (subsetl1a).

mcalibrate:
Change path for alpha. Put binary in bin1. Archive recent improvements to scripts. Fix portability nit on alpha. Bump version, added detector after mirrorside Output detector for center scan line.

dumppol-mod:
New program to convert polarization correction data into hdf.

diff:
Update help to include discussion of bounds parameter.

scrpasmlt:
Add unix path check.

pathnlc:
New NOAA-16 tree tests. Change noaa-16 set point.

tirpack:
Add support for KLM Level-Ib GAC format. KLM GAC data record changes.

tirread:
Add support for KLM Level-Ib GAC format.

modsst:

Print MET and OZONE file names to log file properly. Remove unused variable. Check for ascending or descending if L1b flags are set, but not if geolocation flags are set. Use Day/Night mode to set AscendingDescendingFlg if geolocation is bad. makefile changes for linux.

B.5 Team Interactions

Participated in weekly teleconferences with MCST, PIP, and Oceans science team. MODIS Ocean data short course, Bigelow lab, Maine, July 7-11,2003. Presented papers at the IGARSS, Toulouse, France, July 21-25,2003. Participated in the MODIS Oceans DATA workshop September 4-5 University of Oregon. MODIS AQUA/TERRA Calibration meeting Sept 2003. Attended the MODIS Direct Broadcast meeting, November 2003, Hawaii and presented posters. Participated in Moby calibration round table discussion, Hawaii November 2003. Participated in presentation to NASA Headquarters Terra/MODIS reprocessing recommendations, September 23,2003. White paper report to NASA Headquarters, MODIS calibration status, November 2003.

C. Future Activities

C.1 Processing Development

We will continue to update and maintain the sea surface temperature algorithms as needed. At the time of this writing the exact future role of the University of Miami SCF in regard to MODIS ocean color is yet to be defined.

C.2 Matchup Database

In regard to SST, we will continue to routinely extract 5x5 boxes of MODIS pixels for MAERI and buoy matchups for SST for both SST algorithm coefficient estimation and validation. Validation also continues by comparing retrievals from other sensors, eg. AVHRR, AMSR, ASTER.

C.3 Direct Broadcast

C.4 Systems Support

No upgrades are planned

C.5 Team Interactions

Work is planned with EOS and international teams to improve SST validation, exchange MAERI and buoy matchup observations and Terra/Aqua SST and SST4 global fields. Continue interact with GODAE Global High Resolution SST working group to better define estimation of diurnal thermocline leading to a proper merger of Aqua and Terra day and night SST fields.